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Controlling *Listeria monocytogenes*, *Campylobacter jejuni*, *Salmonella enterica* Typhimurium and *Escherichia coli* O157:H7 in Meat Products by Irradiation Combined with Modified Atmosphere Packaging

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Summary and Implications

Four of the bacterial pathogens that are of major concern to the meat industry, *Listeria monocytogenes*, *Campylobacter jejuni*, *Salmonella enterica* Typhimurium and *Escherichia coli* O157:H7 were studied for their susceptibility to high carbon dioxide atmospheres during irradiation and storage by utilizing high-carbon-dioxide modified atmosphere packages (MAP) compared to vacuum packaging. Frankfurters and cooked pork chops (*L. monocytogenes*), chicken breasts (*C. jejuni* and *S. enterica*) and ground beef (*E. coli* O157:H7) were inoculated with the respective pathogens, packaged in vacuum or MAP and irradiated with doses appropriate to each pathogen. Surviving bacteria were monitored during refrigerated and temperature-abused storage. While irradiation was very effective for reducing the number of pathogens on each product, the use of high carbon dioxide atmosphere in MAP did not increase the effectiveness of irradiation as an antimicrobial treatment. The MAP treatment resulted in less recovery of *L. monocytogenes* than vacuum for cooked pork chops during refrigerated storage, and for *E. coli* O157:H7 on ground beef when exposed to room temperature, but not for the other pathogens or products. Consequently, while irradiation is a very effective means of reducing or eliminating bacterial pathogens on meat products, the addition of a high-carbon dioxide MAP system during storage of the products did not greatly improve the control of these pathogens.

Introduction

Foodborne pathogens continue to be a public health concern for the meat industry. The major concerns include *Listeria monocytogenes* on cooked, ready-to-eat products, *Campylobacter jejuni* and *Salmonella enterica*

Typhimurium on poultry products and *Escherichia coli* O157:H7 on fresh ground beef. While each of these pathogens has its own characteristics and its own set of ideal conditions for growth on meat products such that control measures are somewhat different, all of these pathogens are susceptible to irradiation as a means of reducing or eliminating the pathogen population. However, because irradiation may introduce odor and flavor changes in meat depending on the irradiation dose used, utilizing minimum doses necessary for microbial control is important to maintaining product quality. Adding a supplemental antimicrobial treatment that will suppress growth of bacteria that survive the irradiation process may permit use of lower irradiation doses and better product quality. Modified atmosphere packaging (MAP) offers the opportunity to utilize carbon dioxide gas in the package atmosphere. This gas has been shown to be an effective antimicrobial agent when used in MAP during product storage. However, high concentrations of carbon dioxide will result in discoloration of fresh meat and, as a result, is limited to about 30% of the package atmosphere in typical applications. In 2004, the USDA approved carbon monoxide at 0.5% or less as a MAP gas because it effectively stabilizes meat color during storage. The use of carbon monoxide prevents the discoloration induced by carbon dioxide concentration and permits use of much higher carbon dioxide concentration in MAP without meat color change. The objective of this study was to investigate the use of low dose irradiation combined with a high concentration of carbon dioxide in MAP packages for improved control of four of the major pathogenic bacteria that are of concern to the meat industry.

Materials and Methods

In this study, *L. monocytogenes* survival and growth was evaluated using frankfurters and cooked pork chops as ready-to-eat products, *C. jejuni* and *Salmonella* were assessed using chicken breast meat and *E. coli* O157:H7 was monitored on ground beef patties. Each type of product was inoculated with the respective pathogen and packaged in vacuum or in high carbon dioxide (99.5%) MAP with 0.5% carbon monoxide. A five strain mixture of each pathogen was used for the inoculations with the exception of *Salmonella* where a four strain mixture was used. After inoculation, the packages were irradiated at 0 (control), 0.25, 0.5, 0.75, 1.0, 1.5 or 2.0 kGy, depending on the pathogen targeted. Survival and subsequent growth of each pathogen was monitored for 6 weeks during refrigerated

storage. Un-inoculated samples were also assessed for odor and flavor changes by a sensory panel.

Results and Discussion

There was no difference in radiation sensitivity of *L. monocytogenes* on frankfurters or cooked pork chops in the two packaging environments of vacuum or MAP. However, the high carbon dioxide MAP suppressed growth of this pathogen more effectively than vacuum packaging for the cooked pork chops, particularly in the control (0 kGy) and low-dose treatments (0.5 kGy). Generally, after 6 weeks of refrigerated storage, *L. monocytogenes* counts were 1-2 log greater in vacuum packages of cooked pork chops than in MAP. Increased irradiation dose reduced the number of organisms that survived and MAP packaging, in the case of the cooked pork chops, helped suppress recovery of the organism at the low dose levels. The recovery of this organism on frankfurters did not differ in the two packaging environments.

Both *Campylobacter jejuni* and *Salmonella* were reduced by about 3 log by irradiation doses of up to 0.75 kGy and 1.5 kGy, respectively for these pathogens, and survivors did not grow during refrigerated storage in either of the packaging systems used. The sensitivity of these organisms to irradiation was similar in both vacuum and MAP. When packages with these two pathogens were exposed to room temperature for 48 hours, *Salmonella* increased in number regardless of the packaging system but *C. jejuni* did not. This was not unexpected because *C. jejuni* is a thermophilic organism that grows best at over 30°C. However, this organism remained persistent in the packages during storage and, if given adequate temperature exposure, would be likely to increase in numbers regardless of the packaging system. While irradiation was confirmed as an effective means of reducing the number of these two pathogens on chicken breast meat, there was no apparent advantage of either vacuum or MAP for additional suppression of these organisms during storage. Irradiation odor and sour aroma was observed by the sensory panel when evaluating the un-inoculated raw chicken breast. Consequently, additional treatments to reduce the quality changes induced by irradiation of chicken breast meat would be important for successful application of the irradiation process for this product.

Irradiation sensitivity of *E. coli* O157:H7 was similar in vacuum or MAP as observed for the other pathogens studied. Survivors of the irradiation treatment did not grow in storage in either type of packaging but remained persistent for about three weeks after which the number of organisms declined slowly. However, exposure of the packages to room temperature for 48 hours resulted in an increased number of the pathogen in vacuum packages but not in MAP, suggesting that MAP with high carbon dioxide may provide some additional control of this organism over that of vacuum packaging in the event of temperature abuse. Sensory panel evaluations indicated more off-odor and off-

flavor for cooked beef patties from MAP than from vacuum packages.

The results of this study show that use of high carbon dioxide concentration in MAP does not increase pathogen sensitivity to irradiation treatments over that of vacuum packaging for the pathogens included in this investigation. The use of MAP appeared to provide a limited amount suppression of pathogens during product storage but this appeared to be dependent on the microorganism and the product, such as *L. monocytogenes* on cooked pork chops, and *E. coli* O157:H7 on ground beef. Sensory analysis of the chicken breast meat and the ground beef patties confirmed the odor and aroma changes often observed for irradiated fresh meat products, an issue that is a concern for successful application of irradiation for pathogen control. It is also important to note that the concentration of carbon dioxide (99.5%) used in this study to maximize the potential antimicrobial impact of this gas often results in excessive absorption of carbon dioxide in the water phase of the meat product which can manifest itself in the form of gas bubbles on the interior of the product when the product is cooked.

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